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The Feeding Ecology of the Chesapeake Bay Ospreys and the Growth and Behavior of their Young

Peter Kleppinger McLean
College of William & Mary - Arts & Sciences

THE FEEDING ECOLOGY OF THE CHESAPEAKE BAY OSPREYS AND THE GROWTH AND BEHAVIOR OF THEIR YOUNG

A Thesis

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Peter Kleppinger McLean

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APPROVAL SHEET

This thesis is submitted in partial fulfillment of the requirements for the degree of

Masters of Arts

Peter Kleppinger McLean
Author

Approved, May 1986

Ruth A. Beck
Ruth A. Beck

Mitchell A. Byrd
Mitchell A. Byrd, Chairman

Norman J. Fashing
Norman J. Fashing

Jeffrey R. Lucas
Jeffrey R. Lucas

Stewart A. Ware
Stewart A. Ware

DEDICATION

I dedicate this thesis to Mitchell A. Byrd, Frank C. Craighead, Jr. and John J. Craighead. Without them, there would be fewer of us that appreciate the natural world.

All things, by almighty power, near and far
hidden to each other connected are.
To disturb a flower, is the troubling of a star.

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ABSTRACT

In 1975, as part of a larger study of the reproductive ecology of Ospreys (Pandion haliaetus), Stinson (1976, 1977) recorded the growth and behavior of 11 broods of young of nests along the western shore of the Chesapeake Bay. His findings included the absence of cainism and the prevalence of compatibility among Osprey young, the sequential feeding of the young, and no demonstration of behavior dominance among siblings. He also found that the growth rate (K), as described by the logistic growth equation, was .12 and noted an inverse relationship between brood size and fledging weight.

Ten years later, I studied the feeding ecology of Ospreys inhabiting the same area (and in at least one case the same nest) that Stinson studied. Observation of the growth and behavior of 16 young of seven broods revealed sex-related differential growth, nest switching, nonsequential feeding of the young, substantial amounts of sibling aggression and dominance, and brood reduction. Young that incurred considerable amounts of sibling aggression fledged significantly later. Moreover, the rate of delivery of fish to the nest and the amount of time the male spent perched near the nest have both decreased by approximately 35 percent. This, among other factors, suggests that the availability of food in the Bay was less than in 1975.

Although food quantity and sibling aggression were not correlated, food quality (kilocalories) and aggression were positively correlated ($r=.754$, $df=5$, $P=.05$). Possible explanations for this are discussed. The data suggest that sex of the first-hatched, hatching asynchrony, and ultimately food shortage contribute to the occurrence of sibling aggression and brood reduction.

Based upon observations of fish delivered to the nest, menhaden (Brevoortia tyrannus) constituted 68.2 percent of the Ospreys' diet.

THE FEEDING ECOLOGY OF THE CHESAPEAKE BAY OSPREYS AND THE GROWTH AND BEHAVIOR OF THEIR YOUNG

INTRODUCTION

Stinson (1976, 1977) noted the absence of sibling aggression during his 1975 study of the reproductive ecology of Ospreys (Pandion haliaetus) of the Chesapeake Bay. However, several more recent studies have indicated the existence of sibling aggression and brood reduction in Ospreys (Poole 1979, 1982b, Judge 1980, Roberts 1982, Jamieson et al. 1983, Spitzer 1985, Hagan 1984, Byrd 1983). It has been hypothesized that this behavior is food-related (Poole 1979, 1982b, Byrd 1983). In response to these recent reports, a study of the feeding ecology of the Ospreys inhabiting the western shore of the Chesapeake Bay was undertaken during the summer of 1985. Nest occupants were intensively observed during the nestling and post-fledgling periods in order to ascertain the quality and quantity of fish delivered and to determine what effect these factors may have on the growth and behavior of the young. A decrease of the amount and/or the quality of the food delivered to the young might reflect an increase in sibling aggression, brood reduction, and a retardation of the growth and development of the young.

METHODS AND MATERIALS

A total of seven broods of Ospreys in nests located in Mathews and Lancaster counties, Virginia was studied (for exact nest location, see Appendix A). All nests were approximately 25-125 meters from shore; therefore, the nests and their occupants were easily observable from land and readily accessible by boat. In most study locations the Ospreys were subjected to various amounts of human activity (including our own), but they appeared to easily habituate to such disturbance though we lack supporting data.

Between May 21 and July 25, an assistant and I observed seven nests chosen such that two could be observed simultaneously. We accumulated more than 600 observation hours, or if nests are considered singly, over 1000 hours were amassed. Observation periods of approximately eight hours were randomly arranged such that we gathered a full day of observations of each nest over the four-day observation week. Morning observation periods began at daybreak (approximately 0530 hours) and lasted until 1300 hours. The afternoon period would then begin at 1300 hours and end at nightfall (approximately 2030 hours). An assortment of spotting scopes were used for observation, including a 20 x 60 Nikon, a 40 x 60 Nikon and a 40 x 80 Questar. During the observation periods, all behaviors were

noted, as well as the size, number and species of fish delivered to the nest. To improve on the estimation of fish size, a 48 centimeter wooden rod graduated at 12 centimeter intervals was affixed to the nest. The tarsus length of the adult Ospreys was used for the same purpose. Fish lengths were later converted to grams using length-weight relationships specific for each fish species (Appendix B). We also recorded the number of bites of fish eaten by the nest occupants during three one-minute periods that were randomly spaced. Information on weather, hunting activities, and the amount of time the male spends perched near the nest was also recorded.

During the ten weeks, we visited the nests twice a week to weigh and measure the young. Nest visits were limited to approximately ten minutes. Length measurements of the longitudinal axis of the body, the tail, the culmen, and the tarsus were noted and recorded. Weights were collected using 1000 and 2000 gram Pesola spring scales. Crops were palpated to determine the extent of fullness. The ages of the young were known within one day ,and, in some cases, the exact date of hatching was noted. In nearly all the cases, sex was determined by using tail length (MacNamara 1977), behavior, and feather color. All chicks were banded with U.S. Fish and Wildlife Service aluminum bands as well as colored leg bands to ensure positive identification. Band

weights were subtracted from all subsequent weights. Also, red nail polish was applied to the middle toe of the larger sibling of the brood to allow for identification early in the study. Typewriter correction fluid applied to the crown was used for the same purpose. Later in the study, picric acid (a harmless dye) applied to the neck and upper breast feathers ensured identification as well.

Prey remains were collected during the nest visits. These remains were individually bagged, labeled, and later identified using articulated skeletons, preserved specimens, and the assistance of the curator of the Virginia Institute of Marine Science. Diet composition was then based upon the frequency of occurrence of the prey item.

In July of 1985, we collected samples of each of the fish included in the Ospreys' diet. Samples were dried for ten days at temperatures between 55 and 60^{C}, ground in a Wiley Mill and pelletized. Using a Phillipson Oxygen Microbomb Calorimeter and following the standard procedure for its use, calories per milligram dry weight per sample were ultimately calculated (Appendix C).

Growth curves generated from the logistic equation best represent the growth of Ospreys (Stinson 1977, Ricklefs 1967, 1968, 1976): $W = A/(1+e\ exp[-K(t-t_0)])$, where W = weight at time (age) t, A = asymptote (or maximum weight) of the growth curve, K = the growth rate constant, and

t_0 = age at the inflection point of the growth curve (1/2 of the asymptotic weight). The inverse measure of growth , t_{10-90} (days) = 1.098/(dw/dt), representing the time it takes a young to grow from 10 to 90 percent of its asymptotic weight, was also used (Ricklefs 1976). All regressions, correlations, and other statistical analyses were performed on the College of William and Mary's 9955 Prime computer using the SPSSX (1983) and Minitab (Ryan 1985) software packages.

RESULTS

A. Growth Rates, Fledging Weights, and Fledging Age of the Young

A total of 16 chicks in seven broods was studied. Two chicks died within the first ten days of the study leaving five broods of two, one brood of one, and one brood of three young (Table 1). Four of the five two-young broods were comprised of a male and a female, but in brood three, we were not absolutely certain that Y1 was in fact a female, though we treated it as such. The one-young brood contained a female, and two females and a male comprised the three-young brood.

Rank, as determined by the young's weight relative to its siblings, was generally maintained throughout the nestling period (Figure 1). This held true for all the chicks of all the broods, except number seven. In this brood, no switching of rank was detected until the latter part of nestling development when the young weighed more than 1100 grams (Figure 2). The two females of this brood attained greater weight than the male (Table 1; Figure 2).

Using the asymptotic weight of each young, the average growth rate constant (K) for the fourteen young was .138 (S.D.=.0178, N=14). The male K was .141 (S.D.=.0240, N=6) and that of the females was .136 (S.D.=.0131, N=8). These growth rate constants were not significantly different

Table 1

SEX, HATCH DATE, ASYMPTOTIC WEIGHT, GROWTH RATE, AND AGE OF YOUNG AT FLEDGING

Brood	Young[1]	Sex	Hatch Date	Asymptotic Weight[2]	Growth Rate[3]	Fledging Age[4]
1	Y1	F	5/24/85	1765	.122	50
	Y2	M	5/24/85	1445	.139	50
2	Y1	M	5/20/85	1350	.166	49
	Y2	F	5/18/85	1650	.140	50
3	Y1	F	5/13/85	1415	.145	46
	Y2	M	5/14/85	1390	.162	47
4	Y1	M	5/19/85	1400	.145	50
	Y2	F	5/18/85	1725	.145	51
5	Y1	F	5/24/85	1695	.158	55
	Y2	M[5]	5/25/85	1215	.134	60
	Y3	-[6]	5/24/85	--	--	--
6	Y1	F	5/19/85	1700	.121	56
	Y2	-[7]	5/24/85	--	--	--
7	Y1	F	5/16/85	1810	.127	53
	Y2	F[5]	5/17/85	1815	.131	55
	Y3	M	5/15/85	1525	.099	54

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[1] arbitrary designation

[2] in grams

[3] K - based on asymptotes for each individual

[4] in days

[5] lower ranking young

[6] died at six days of age

[7] died at ten days of age

Figure 1. Growth rates of the young of brood one.

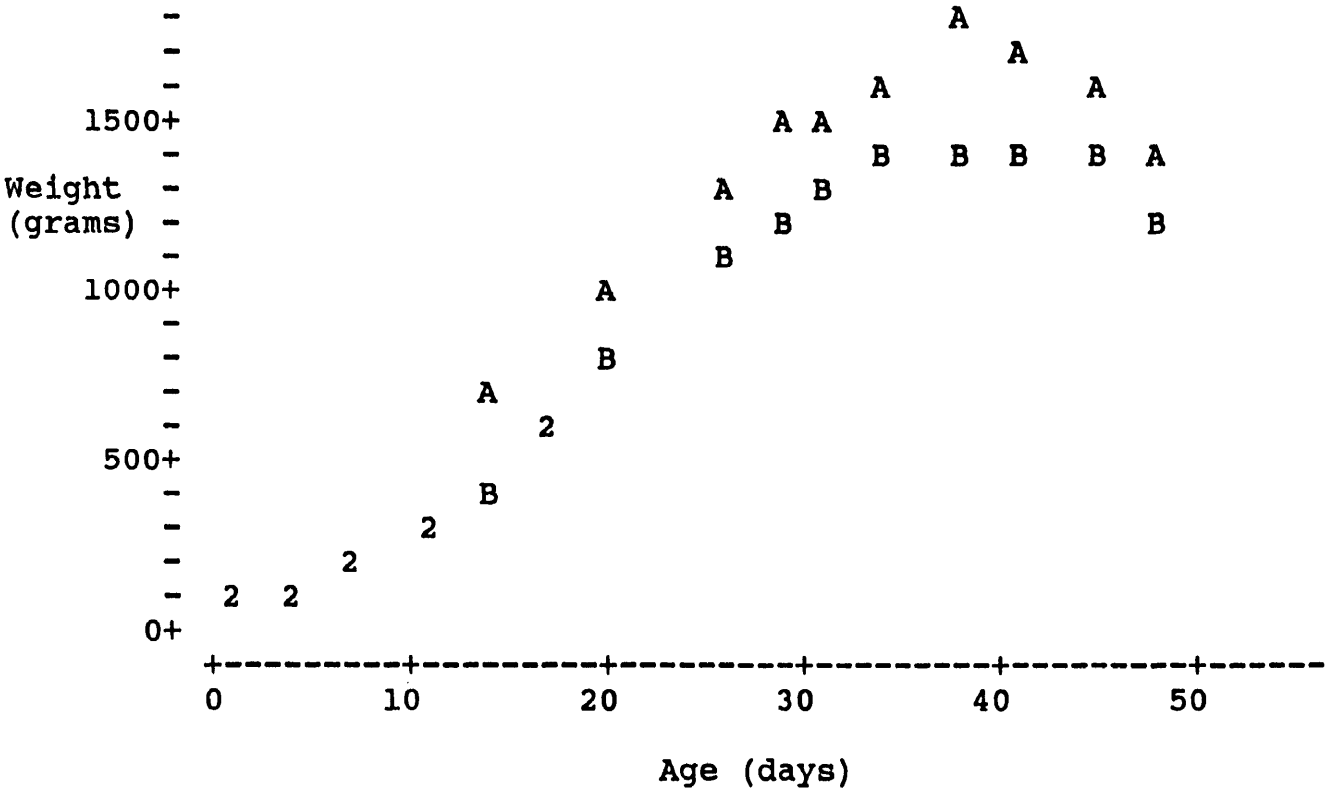
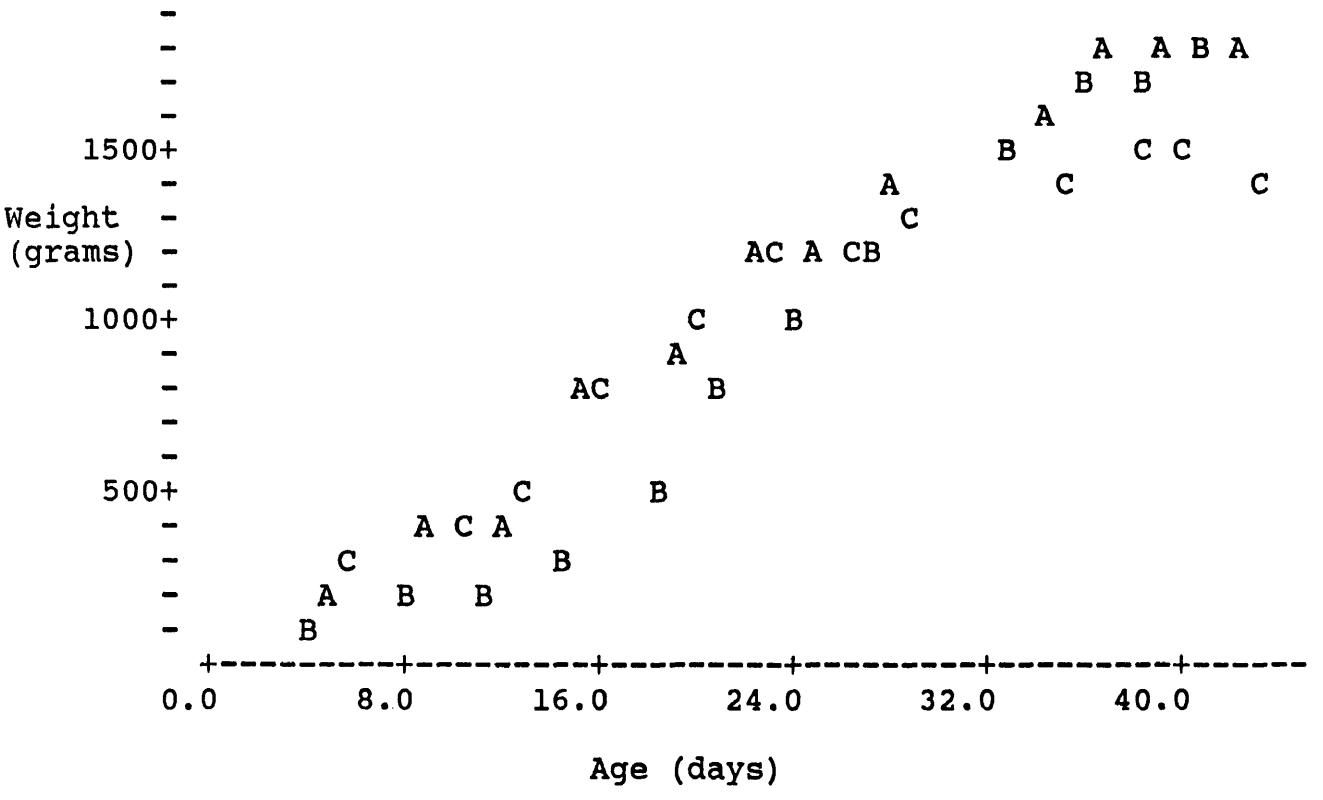

Weight
(grams)
1500+
1000+
500+
0+
0
10
20
30
40
50
Age (days)
A = Young 1
B = Young 2

Figure 2. Growth rates of the young of brood seven.


1500+
Weight
(grams)
1000+
500+
0.0
8.0
16.0
24.0
32.0
40.0
Age (days)
A = Female (Y1)
B = Female (Y2)
C = Male (Y3)

(oneway anova, P=.625). The time required for the males and the females to grow from 10 to 90 percent of their asymptotic weight was 32.068 days (S.D.=6.482, N=6) and 32.510 days (S.D.=3.041, N=8) respectively.

In order to compare growth rates of Ospreys with those calculated by Stinson (1977), new asymptotic values were estimated. Since asymptotic weight near fledging time is inversely proportional to brood size (Stinson 1977), the largest average weight of the young of that particular brood size was used to represent the asymptote (Stinson 1977). Therefore, using 1700 grams to represent the asymptote or maximum weight of the one-young brood, 1605 grams to represent that of the two-young brood and 1717 grams to represent that of the three-young brood, the growth rate constant (K) of the fourteen young was .130 (S.D.=.043, N=14). The time required for the young to grow from 10 to 90 percent of the asymptotic weight was 37.229 days (S.D.=11.456, N=14).

Growth rates as figured above (Ricklefs 1967, 1968, 1976; Stinson 1977) reflect the rate of growth as a percentage of the asymptote. In Ospreys, since the male and female asymptotic weights are significantly different (Table 2), and both sexes take about the same time to fledge (Table 3), ostensibly their actual rates of growth must be different. Graphic analysis of the male and female growth

Table 2

ONEWAY ANOVA OF ASYMPTOTIC WEIGHTS BETWEEN MALE AND FEMALE NESTLINGS[1]

Sex	N	Mean Weight (grams)	Standard Deviation
Male	5	1365.000	90.623
Female	5	1645.000	148.619
TOTAL	10	1505.000	187.735

Source	D.F.	Sum of Squares	Mean Squares	F ratio	F prob
Between Sexes	1	1.96000E+05	1.9600E+05	1.294E+01	.007
Within Sexes	8	121200.000	15150.00		
TOTAL	9	317200.000			

[1]broods 1 - 5 (each composed of a male and a female)

Table 3

ONEWAY ANOVA OF FLEDGING TIMES BETWEEN MALE AND FEMALE NESTLINGS[1]

Sex	N	Mean Weight (grams)	Standard Deviation
Male	5	51.000	5.292
Female	5	50.600	2.881
TOTAL	10	1505.000	187.735

Source	D.F.	Sum of Squares	Mean Squares	F ratio	F prob
Between Sexes	1	4.000E-01	4.000E-01	2.204E-02	.886
Within Sexes	8	145.200	18.150		
TOTAL	9	145.600			

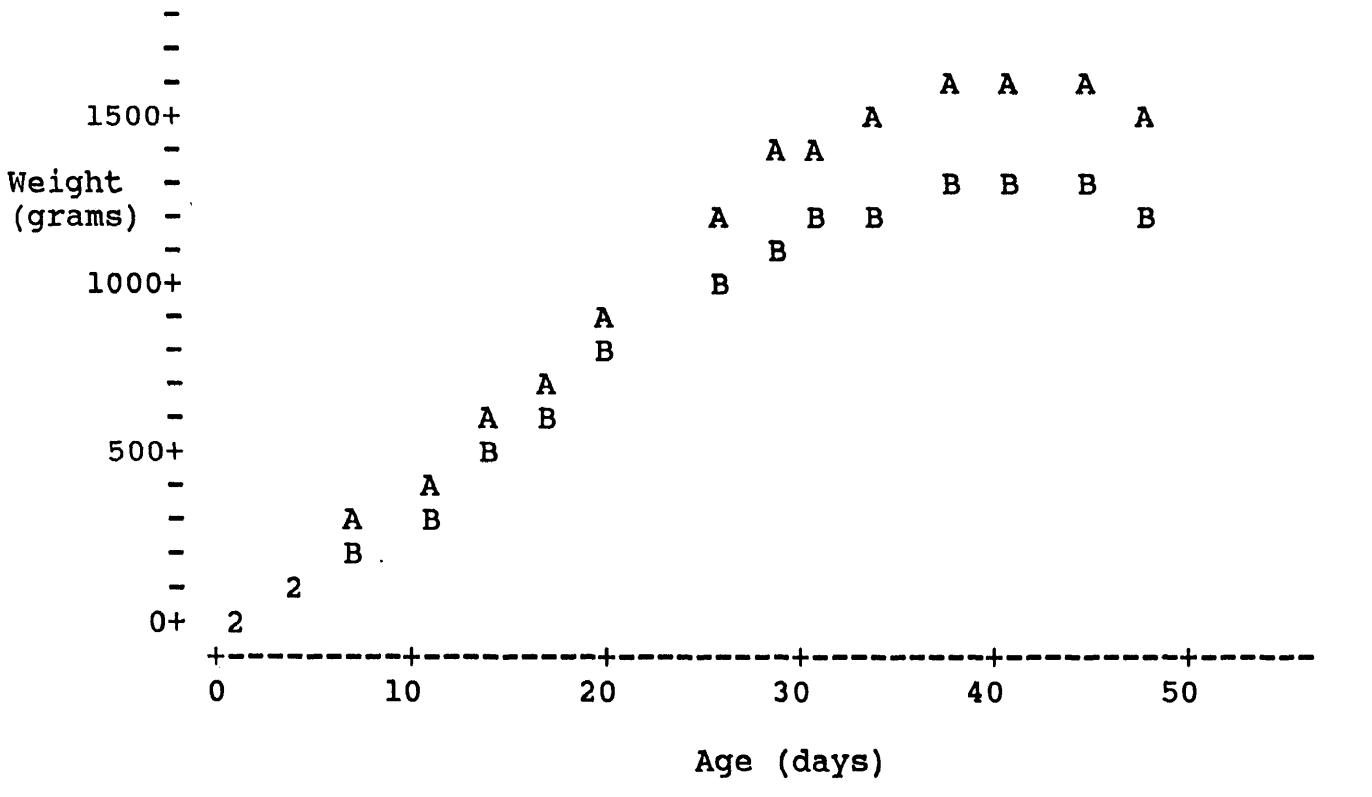
[1]broods 1 - 5 (each composed of a male and a female)

curves suggest that the rates are in fact different (Figure 3).

Between broods, a number of comparisons are of note. The young of broods five, six and seven fledged significantly later than young in some of the other broods (Table 4). If only the two-young broods are compared, the young of brood five fledged significantly later than the young of the other broods (Table 5). Between all seven broods, results of an analysis of covariance reveal that the growth rates (K) of the young of these broods were significantly different (P=.027); however, between the two-young broods growth rates were not significantly different (analysis of covariance, P=.469). This suggests that the young of broods of one and three young (broods six and seven respectively) grew at different rates than the young of the two-young broods. In terms of asymptotic weights of the young, there was no significant difference among the two-young broods (oneway anova, P=.899).

Examination within the broods is revealing. Low-ranking young (Y2 of broods five and seven) had later fledging dates (mean = 57.5 days) than the other young. Furthermore, the growth rate of the low-ranking young - a male - of brood five was substantially less than the growth rates of the other males of the two-young broods (Figure 4). Even though this male was eleven days older than the other

Figure 3. Average growth rates of female and male young of broods one through five.



A = Average Female Growth Rate B = Average Male Growth Rate

Table 4

RESULTS OF A STUDENT - NEWMAN - KEULS MULTIPLE RANGE TEST COMPARING FLEDGING TIMES BETWEEN BROODS

Brood	Brood 1	2	3	4	5	6	7	Mean Fledging Time (days)	Brood Size	Standard Deviation
1								50.000	2	0.000
2								49.500	2	0.707
3								46.500	2	0.707
4								50.500	2	0.707
5	*	*	*	*				57.500	2	3.536
6			*	*				56.000	1	---
7			*	*				54.000	3	3.820
TOTAL								51.957	14	3.8201

*denotes pairs of broods significantly different at the 0.05 level

Table 5

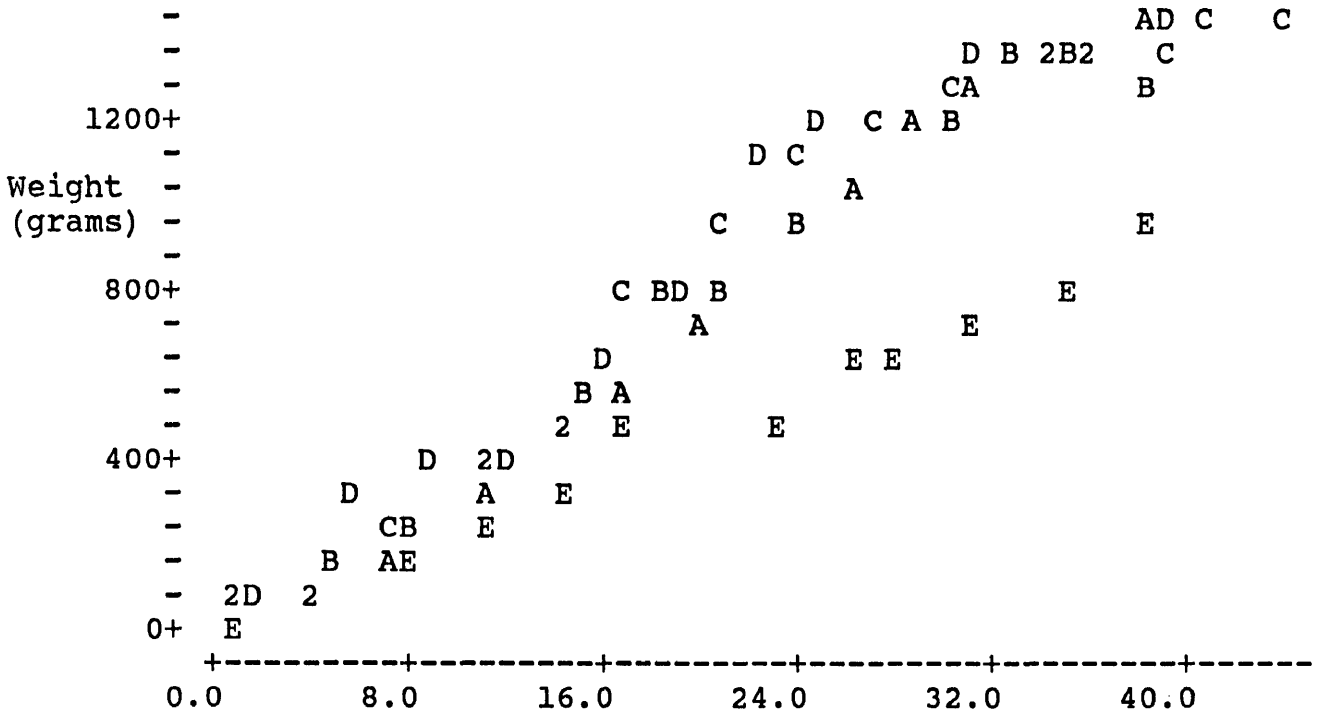
RESULTS OF STUDENT - NEWMAN - KEULS MULTIPLE RANGE TEST COMPARING FLEDGING TIMES BETWEEN ALL TWO-YOUNG BROODS (Broods 1 - 5)

Brood[1]	Mean Fledging Time (days)	Brood Size	Standard Deviation
1	50.0	2	0.000
2	49.5	2	0.707
3	46.5	2	0.707
4	50.5	2	0.707
5	57.5	2	3.536
TOTAL	50.8	10	4.022

[1]Broods connected by line are not significantly different ($p>0.05$).

Brood unconnected (Number 5) significantly different ($p<0.05$).

Figure 4. Growth rates of the male young of broods one through five.


Weight (grams)
1200+
800+
400+
0+
0.0
8.0
16.0
24.0
32.0
40.0
Age (days)
A = Brood 1 Male
B = Brood 2 Male
C = Brood 3 Male
D = Brood 4 Male
E = Brood 5 Male

males at the last weighing before fledging, it had the lowest asymptotic weight and the shortest body length of all Osprey young (Tables 1 and 6). The low-ranking female of brood seven had the shortest tail and wing chord of all female young and it along with the female of brood 6 had the shortest body length of all other female young (Table 6).

Table 6

BODY, CULMEN, TARSUS, TAIL AND WING CHORD LENGTHS[1]

Brood	Young	Sex	Age (days)[2]	Body	Culmen	Tarsus	Tail	Wing Chord
1	Y1	F	48	50.8	3.0	7.0	16.5	36.8
	Y2	M	48	45.7	2.8	6.7	16.5	36.8
2	Y1	M	47	45.7	2.8	6.7	15.2	35.6
	Y2	F	47	52.1	3.0	7.0	17.8	39.4
3	Y1	F	44	53.3	3.0	7.0	16.5	38.0
	Y2	M	45	47.0	2.7	7.0	14.0	33.0
4	Y1	M	46	49.5	2.8	7.0	15.2	38.0
	Y2	F	47	50.8	3.0	7.3	17.8	39.4
5	Y1	F	52	50.8	3.0	7.3	15.9	38.0
	Y2	M	57	43.2	3.0	7.0	15.2	36.8
6	Y1	F	53	49.5	3.0	6.7	16.5	39.4
7	Y1	F	50	54.6	3.0	7.0	17.8	39.4
	Y2	F	52	49.5	3.0	7.0	15.2	35.6
	Y3	M	51	52.1	3.0	7.0	17.8	40.1

[1]measurements in centimeters

[2]age at last weighing before fledging

B. Brood Reduction

Brood reduction was limited to two of the seven broods. One of the chicks (Y3) of brood five died at approximately six days of age and was found a day later, May 31, 1985. The second-hatched young (Y2) of brood six was ten days old at death and was found less than a day afterward (June 4, 1985). Both bodies were found in the nest, nearly intact, and with little evidence of external injury. Autopsies performed by a local veterinarian implicated malnutrition as the probable cause of death.

C. Feeding Behavior of Ospreys

The male Osprey did virtually all the hunting for the brood with the exception of nest five of which the female also contributed to the foraging efforts three weeks into the nestling period. Approximately 18 percent (58 of 319) of the fish delivered to the nest had been decapitated - the heads having been eaten by the male.

Once the fish were brought to the nest, the female fed the young small portions or bites. The adult male was never observed feeding the young. It was our impression that the nestlings nearest the female, which were nearly always the ranking young, were fed first, and, in many instances, the most. In terms of the average number of bites delivered to the young of nest five, the ranking young (Y1) received significantly more than the low-ranking bird (Y2) (Table 7). On twenty separate occasions, low-ranking young - in particular the male of nest five (Y2) and the female (Y2) of nest seven - were never fed until the ranking sibling(s) stopped feeding. In brood seven, although the mean number of bites did not significantly differ between the ranking (Y3) (mean=3.944, S.D.=4.851, N=108) and low-ranking (Y2) (mean=4.435, S.D.=5.601, N=108) young (oneway anova, P=.492), on 29 of 42 occasions the low-ranking young (Y2) was not fed. On those other occasions, aggression between

Table 7

BITES OF FISH EATEN BY BROOD FIVE NESTLINGS

Nestling	Mean Number of Bites	Standard Deviation	N
Ranking	6.750	5.575	44
Low-ranking	3.591	5.168	44
TOTAL	5.170	5.575	88

Source	D.F.	Sum of Squares	Mean Squares	F ratio	F prob
Between Groups	1	2.1956E+05	2.1956+02	7.599E+00	.0071
Within Groups	86	2484.8864	28.8940		
TOTAL	87	2704.4432			

Y1 and Y3 kept one or the other from eating.

Consistent with these observations is the fact that on two of fourteen occasions, the crops of low-ranking young were found empty while those of the ranking young were full. Of 183 examinations of all the young's crops, 55 percent were empty.

Most notable was the observation of 32 individual incidents of aggression between the siblings. All multi-young broods except one had at least one such incident, and eight and eighteen aggressive actions took place between young of broods five (two young) and seven (three young) respectively. These aggressions were commonly manifested by a peck or a blow delivered to the back of the neck or head. Individual aggressive actions would last as long as 20 seconds. After exposure to this behavior, a simple outstretched neck or head raised (dominant posture) on the part of the aggressor seemed adequate in provoking a submissive posture - head and neck lowered often accompanied by a flattening of the body against the nest - from the less dominant bird. Pecks to the tail were also observed. Our field data provide more details of this behavior (Appendix E).

Such behavior was noted throughout the nestling and fledgling periods and was not observed to be more frequent during one period of development than another. Thirty of

thirty-two attacks occurred during feeding. Once the aggressive chick was completely fed (appeared to have a full crop), the aggression would usually cease. The aggressor was nearly always the heaviest (ranking) young, though the male of nest seven, in spite of losing weight (rank), maintained its dominance over the two females. In 35 of 48 instances, the low-ranking young were totally neglected during feeding. Victims of the aggression incurred substantial feather and epidermis injury, but most detrimental was the loss of access to food and the subsequent retardation of growth and development (Table 6; Figure 4). Indeed, such food deprivation was probably responsible for the early death of the young of nests five and six. In general, a marked disparity was evident between the dominant and subordinate young in terms of size, weight and overall appearance of health (Tables 1, 2, and 6; personal observation).

Additionally, our field notes indicate behavior among the occupants of nest five not witnessed at any of the other nests. In five of twenty of our eight-hour observation periods, at least one comment was made about the vocal nature of the adult female and the low-ranking young. All the vocalizations appeared to be associated with food. Our field notes elaborate on this behavior (Appendix E).

Our impression was that the vocalizations appeared to

provoke the adult male to hunt and ultimately to return with more food. In fact, on one occasion, subsequent to an episode of calling by the adult female, the male returned with two fish - menhaden (Brevoortia tyrannus) - one in each set of talons.

Moreover, the female's hunting efforts appeared to be in response to vocalizations of the low-ranking young (Y2). Our notes (Appendix E) indicate the low-ranking young (Y2) calls, and a few minutes later, the female leaves to hunt. During the nestling period, we noted twelve hunting forays of the female of nest five. She delivered nine fish, all menhaden, of an average size of 20.018 centimeters (S.D.=7.348, N=9). This average is not significantly different (oneway anova, P=.2929) than that delivered by the male (mean=17.858, S.D.=5.383, N=57). Furthermore, the proportion of food eaten by the adult female of nest five was greater than the proportion eaten by the adult females of the other two-young broods (Table 8).

Of the prey remains collected at all the nests, 68 percent (151 of 222) were from nest five. Included in the nest five prey remains were whole and partially eaten fish that had dried at the nest apparently after being left uneaten. Consistent with this was that on at least two occasions, we did note that the adult female would leave a portion of the fish uneaten.

Table 8

PERCENTAGE OF TOTAL BITES OF FISH EATEN BY THE ADULT FEMALES OF THE TWO-YOUNG BROODS

	Female Bites	Total Young Bites	Total Bites	Percent of Total Eaten By Female
Brood 1	157	503	660	23.8
Brood 2	162	563	725	22.3
Brood 3	167	589	756	22.1
Brood 4	225	797	1022	22.0
Brood 5	276	516	792	34.8

Lastly, during four different observation periods, we noted the prevalence of vocalization on the part of the adult female of nest six. And, on at least one occasion, we made an observation of the vocal nature of the young of nest seven.

D. Diet Composition, Quantity and Quality of Prey Delivered to the Nest and Rates of Delivery

Based on our observations, atlantic menhaden (Brevoortia tyrannus) comprised 68.2 percent of the diet. American eel (Anguilla rostrata) made up 4.2 percent of the diet, while white perch (Morone americana), oyster toadfish (Opsanus tau), atlantic croaker (Micropogonias undulatus), and summer flounder (Paralichthys dentatus) each comprised approximately three percent of the diet. During the ten weeks of observation, we recorded fifteen different species of fish delivered to the nest (Table 9). Between broods, diet composition was varied (Table 10); however, nearly all the broods received at least 50 percent menhaden. In fact, the diet of the nest five occupants was 83 percent menhaden.

Analysis of prey remains revealed that menhaden constituted 64.9 percent, while oyster toadfish, needlefish (Strongylura marina), white perch, atlantic croaker and sunfish (Lepomis macrochirus) together composed 23.1 percent (Table 11). Summer flounder, bluefish (Pomatomus saltatrix) and American eel were also represented in the remains.

In terms of the amount and quality of fish delivered to the nest, a few between brood comparisons are of note. The occupants of nest seven were the recipients of the greatest amount of food (Table 12). Of the two-young broods, the females and young of broods four and five received the

Table 9

DIET COMPOSITION [1]

Species	Number	%
Atlantic Menhaden (*Brevoortia tyrannus*)	258	68.2
American Eel (*Anguilla rostrata*)	16	4.2
White Perch (*Morone americana*)	13	3.4
Oyster Toadfish (*Opsanus tau*)	13	3.4
Atlantic Croaker (*Micropogonias undulatus*)	13	3.4
Summer Flounder (*Paralichthys dentatus*)	11	2.9
Hogchoker (*Trinectes maculatus*)	8	2.1
White Catfish (*Ictalurus catus*)	4	1.0
Cutlassfish (*Trichiurus lepturus*)	3	0.8
Spotted Seatrout (*Cynoscion nebulosus*)	2	0.5
Needlefish (*Strongylura marina*)	1	0.3
Butterfish (*Peprilas triacanthus*)	1	0.3
Harvestfish (*Peprilus alepidotus*)	1	0.3
Sunfish (*Lepomis macrochirus*)	1	0.3
Spanish Mackerel (*Scomberomorus maculatus*)	1	0.3
Unknown	32	8.5
TOTAL	378	99.9

[1] based upon fish delivered to the nest

Table 10

DIET COMPOSITION OF BROODS ONE THROUGH SEVEN[1]

	Brood 1	Brood 2	Brood 3	Brood 4
Atlantic Menhaden	33(75.0)[2] 18.703, 2.058, 30	19(48.0) 20.453, 5.776, 19	27(64.3) 18.704, 3.160, 27	40(68.8) 19.807, 3.828, 40
American Eel		1(2.5) 35.600, -- , 1	1(2.4) 33.020, -- , 1	7(11.9) 31.914, 14.786, 7
White Perch	1(2.4) 15.200, -- , 1	2(5.0) 16.500, 1.839, 2	4(9.5) 22.850, 6.584, 4	1(1.7) 7.620, -- , 1
Oyster Toadfish		2(5.0) 16.500, 1.839, 2		3(5.1) 21.167, 1.501, 3
Atlantic Croaker	1(2.4) 25.400, -- , 1	1(2.5) 30.500, -- , 1	2(4.8) 22.850, 3.606, 2	
Summer Flounder	1(2.4) 15.200, -- , 1	5(12.5) 17.260, 4.895, 5		1(1.7) 20.300, -- , 1
Hogchoker		4(10.0) 15.200, 0 , 4		
White Catfish		2 (5.0) 10.200, 0 , 2		1(1.7) 25.400, -- , 1

[1] based on fish delivered

[2] listed as follows: Number of fish, (Percent of diet)
Mean Size (cm), Standard Deviation, N

Table 10

DIET COMPOSITION OF BROODS ONE THROUGH SEVEN
(Continued)

	Brood 1	Brood 2	Brood 3	Brood 4
Cutlassfish				
Spotted Seatrout			1(2.4) 22.900, -- , 1	1(1.7) 33.020, -- , 1
Needlefish	1(2.4) 30.500, -- , 1			
Butterfish				
Harvestfish	1(2.4) 20.300, -- , 1			
Sunfish				
Spanish Mackerel				
Unknown	4(9.5) 17.800, 0 , 1	4(10.0) 14.600, 6.667, 4	7(16.7) 18.280, 3.302, 5	5(8.5) 15.200, 8.776, 3
TOTAL	42	40	42	59

Table 10

DIET COMPOSITION OF BROODS ONE THROUGH SEVEN
(Continued)

	Brood 5	Brood 6	Brood 7
Atlantic Menhaden	59(83.0) 18.379, 5.200, 58	39(65.0) 18.354, 4.503, 39	43(67.2) 20.864, 5.096, 21
American Eel		1(1.7) 25.400, -- , 1	6(9.4) 33.883, 5.948, 6
White Perch		4(6.7) 27.325, 11.046, 4	1(1.6) 20.300, -- , 1
Oyster Toadfish	1(1.4) 20.300, -- , 1	7(11.7) 18.129, 2.292, 7	
Atlantic Croaker	1(1.4) 22.900, -- , 1	3(5.0) 30.500, -- , 1	5(7.8) 20.800, 4.542, 5
Summer Flounder			4(6.3) 27.300, 2.437, 4
Hogchoker	2(2.8) 10.200, -- , 2	1(1.7) 20.300, -- , 1	1(1.6) 15.200, -- , 1
White Catfish	1(1.4) 20.300, -- , 1		

Table 10

DIET COMPOSITION OF BROODS ONE THROUGH SEVEN
(Continued)

	Brood 5	Brood 6	Brood 7
Cutlassfish	1(1.4) 27.900, -- , 1	2(3.3) 15.300, -- , 1	
Spotted Seatrout			
Needlefish			
Butterfish			1(1.6) 20.300, -- , 1
Harvestfish			
Sunfish			1(1.6) 15.200, -- , 1
Spanish Mackerel			1(1.6) 45.700, -- , 1
Unknown	6(8.5) 10.150, 7.142, 2	3(5.0) 22.850, 10.819, 2	1(1.6) 12.700, -- , --
TOTAL	71	60	64

Table 11

DIET COMPOSITION[1]

Species	Percent of Total Remains
Atlantic Menhaden (*Brevoortia tyrannus*)	64.9
Oyster Toadfish (*Opsanus tau*)	8.6
Atlantic Needlefish (*Strongylura marina*)	6.8
White Perch (*Morone americana*)	4.5
Atlantic Croaker (*Micropogonias undulatus*)	1.8
Sunfish (*Lepomis macrochirus*)	1.4
Summer Flounder (*Paralichthys dentatus*)	0.9
Bluefish (*Pomatomus saltatrix*)	0.9
American Eel (*Anguilla rostrata*)	0.4
Unknown	9.9
TOTAL	100.1

[1]based upon prey remains.

Table 12

QUANTITY (CENTIMETERS) OF PREY DELIVERED TO THE NESTS[1]

	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6	Nest 7
Total	667.7	746.6	789.7	1211.2	1198.1	1089.1	1440.0
	19.077[2]	18.666	19.742	21.250	18.153	19.448	22.500
	(3.111, 35)	(6.424, 40)	(4.327, 40)	(7.760, 57)	(5.515, 66)	(5.708, 56)	(7.027, 64)

[1] during the nestling period

[2] listed as follows: Mean (Standard Deviation, N)

greatest amount of fish. Conversely, the occupants of brood one received the least amount of fish. Similarily, the greatest number of calories were delivered to those Ospreys of nests five, six and seven (Table 13). The nest one occupants received the least number of calories during the nestling period.

Results listed in Table 14 indicate the Ospreys of all broods studied in 1985 appeared to be getting an adequate amount of kilocalories per day to meet their average daily energy requirements.

The average rate of delivery of fish to the nest was .351 fish per hour (S.D.=.143, N=52). Prey delivery rates were highest to nests five, six and seven (Table 15).

Table 13

QUALITY OF PREY (CALORIES) DELIVERED TO THE NESTS[1]

	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6	Nest 7
Total	6,084,371	9,058,745	6,684,163	7,563,928	17,054,382	13,277,275	17,665,809
	243374.840[2]	312369.828	290615.783	302557.120	310079.673	323835.967	375868.277
	(110478.3)	(385119.8)	(172756.2)	(215328.8)	(395008.9)	(282724.3)	(385668.9)
	(25)	(29)	(23)	(25)	(55)	(41)	(47)

[1] during the nestling period

[2] listed as follows: Average
(Standard Deviation)
(N)

Table 14

KILOCALORIES DELIVERED TO THE NEST[1] AND THE AVERAGE DAILY ENERGY REQUIREMENT[2]

	Total Kilocalories	Number of Days	Kilocalories Per Day[3]	Average Daily Energy Requirement[4]
Nest 1	6084.4	7.5	811.2	540
Nest 2	9058.8	7.0	1294.1	540
Nest 3	6684.2	6.0	1114.0	540
Nest 4	7563.9	7.0	1080.6	540
Nest 5	17054.4	9.0	1894.9	540
Nest 6	13277.3	8.0	1660.7	413
Nest 7	17665.8	7.0	2523.7	667

[1]during the nestling period

[2]based on the Wiens and Innis (1974) simulation model in Lind (1976)

[3]based on a full day of observation

[4]based on 286 Kcal/day for an adult Osprey and 127 Kcal/day for an Osprey nestling

Table 15

PREY DELIVERY RATES[1]

	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6	Nest 7
Total Number of Fish	42	40	42	59	71	60	64
Total Number of Observation Hours	144	152	160	160	152	160	152
Rate (Fish/Hour)	.292	.263	.262	.369	.467	.375	.421

[1] during the nestling and post-fledgling periods

E. Correlations Between Sibling Aggression and Prey Quality and Quantity.

In terms of the seven broods, sibling aggression and the quality of prey delivered to the nest are positively correlated ($r=.754$, $df=5$, $P=.05$; Table 16). However, there is no correlation between sibling aggression and the quantity (total centimeters) of prey delivered to the nest ($r=.652$, $df=5$, $P>.05$).

Table 16

AMOUNT AND QUALITY OF PREY DELIVERED AND THE NUMBER OF SIBLING ATTACKS

	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6	Nest 7
Sibling Attacks	1	2	3	0	8	0	18
Amount of Prey (cm.)	667.7	746.6	789.7	1211.3	1198.1	1089.1	1440.0
Amount of Prey (Kcal.)	6084.4	9058.7	6684.2	7563.9	17054.4	13277.3	17665.8

F. Male Perch Time Near the Nest

The male Osprey spent an average of 29.932 percent (S.D.=14.949, N=52) of the daylight hours perched near the nest. Inspection of Table 17 reveals the male of nest seven was inactive the least amount of time while the male of nest six was inactive the most.

Table 17

MALE PERCH TIME NEAR THE NEST[1]

	Total Perch Time (Hours)	Total Observation Time (Hours)	Percent
Nest 1 - Male	45.333	120.0	37.8
Nest 2 - Male	36.083	105.0	34.4
Nest 3 - Male	17.483	82.5	21.2
Nest 4 - Male	33.417	105.0	31.8
Nest 5 - Male	31.850	135.0	23.6
Nest 6 - Male	53.333	120.0	44.4
Nest 7 - Male	12.350	97.5	12.7

[1]during the nestling period

G. Nest Switching Behavior

On seven occasions soon after fledging, the young of nests one and two and the young of nests three and four were observed on or near nests other than their own. For example, the two young of brood two would join the two young of brood one at nest one. At least once, as many as six fledglings would gather on this nest or its supporting platform (six includes two unidentified young that perhaps came from one of the several productive nests nearby). Here, all the young would wait for the food to be delivered by either adult of nest one. If a nest two adult arrived with food, the adult would only deliver to its nest or its supporting structure approximately 25 meters from nest one. At nest two, only the young of this nest would receive food after making the short flight over from nest one. We never observed intruder young (unmarked young) at nest two. With the arrival of food, the young would aggressively rush for the fish held by the adult. These food deliveries were not without fights, as our field notes indicate (Appendix F). On two of four occasions, the young of the nest to which fish were delivered were the fortunate recipients; the other two times, the intruders succeeded in getting the fish. The adults never seemed to distinquish between their young and others, nor would they attempt to interfere with

the aggression. Early in the fledgling period, mature and immature Ospreys alike appeared to tolerate this nest switching behavior as attested by our field notes (Appendix F). However, later in the fledgling period this tolerance seemed to wane.

After July 16, no further nest switching was observed even though the young of the broods remained in the vincinity of their nests through at least August 2, 1985.

DISCUSSION

Clearly, at least in comparison to 1975, sibling aggression has become a relatively common behavior of Osprey nestlings of the Chesapeake Bay. In this paper, I have documented the occurrence of thirty-two incidents of sibling aggression and two occurrences of brood reduction. In his study of the development of behavior in nestling Ospreys, Roberts (1982) documented the aggression between siblings of two nests. In one case, the adults abandoned an 18 day old young (Roberts personal communication). Spitzer (1985) has for the past three years monitored Osprey productivity in several areas of the Bay's eastern shore, and, in at least one area, has noted substantial brood reduction of approximately 60 percent. Previous to the studies of Roberts (1982), Spitzer (1985) and Byrd (1983), there have been no documented reports of sibling aggression or brood reduction among Chesapeake Bay Ospreys. In fact, Stinson (1976, 1977) clearly indicated that no signs of sibling incompatibility existed during his 1975 study of the reproductive behavior of Osprey inhabiting the western shore of the Bay. As he stated (1977), "... during 230 hours of observing broods of more than one young, I never saw any interaction which suggested that a chick was being harmed or threatened by a sibling". He further noted (1976):

> The feeding adult seemed to feed all chicks which gaped or called for food. Consistent with that impression is the fact that I never visited a nest and found a chick with a empty crop... A hungry chick might call while a sibling was eating, but during the 230 hours of observing broods of more than 1 chick, I never saw a chick attack, threaten or take a fish from an eating sibling.

In 1985, not only did we observe 32 sibling attacks, but threatening postures and the taking of fish were common behaviors. Crop examinations during our nest visits revealed empty crops more than half the time. In 1975, the young were fed sequentially (Stinson 1976). In 1985, in many instances, the young dominated each other - through aggression and/or posturing - and, as a consequence, feeding of the young was often nonsequential. Ranking young were fed repeatedly and low-ranking young were often ignored.

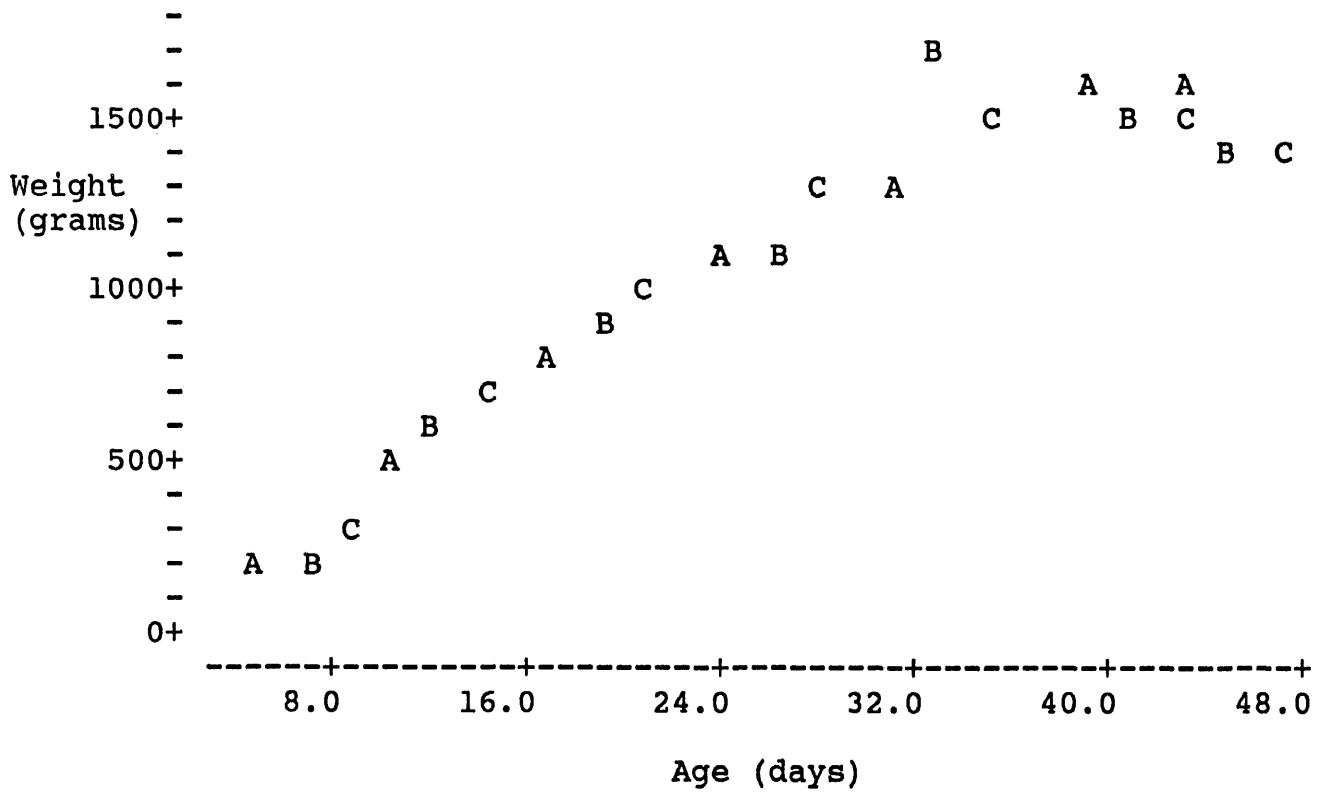
Other contrasts between the 1975 and 1985 results exist (for a summary, see Table 18). Although Stinson found the rank of a chick would change from one weighing period to the next (Figure 5), all the young of all broods studied in 1985 maintained their rank with the exception of the young in nest seven. In this nest, change in rank can most likely be attributed to the sex of the young. The male's (Y3) maximum weight was eventually eclipsed by that of the two females whose weights varied little towards the end of the nesting period. In review of his 1975 data, Stinson (1977) states,

Table 18

COMPARISON OF STINSON'S (1975) AND MCLEAN'S (1985) DATA

	1975	1985
Total Number of Young	27	16
Total Number of Nests	11	7
Incidents of Sibling Aggression	0	32
Incidents of Brood Reduction	0	2
Percentage of Crops Empty	0	55
Sequential Feeding	YES	NO
Rank of Young Changes	YES	NO
Adult Males Feed Young	YES	NO
Adult Females Hunt During Nestling Period	NO	YES
Growth Rate Constant	.12	.13
Average Asymptotic Weight (grams)	1587	1564
Average Fledging Age (days)	51	52
Percent Inactive Time	43.0	29.9
Rate of Fish Delivery (Fish/Hour)	.527	.351

Figure 5. Growth rates of three young Ospreys of brood 24 (Stinson 1976).


Weight
(grams)
1500+
1000+
500+
0+
8.0
16.0
24.0
32.0
40.0
48.0
Age (days)
A = Young
B = Young
C = Young

"...it was not uncommon to see the male feed the chicks on occasion". In over 640 hours of observation in 1985, we never saw the males feeding the young. Futhermore, none of the adult females of the 1975 study contributed substantially to the hunting efforts until the fledgling period as is typical of female Ospreys (personal observation). In 1985, the female of brood five began hunting three weeks into the nestling period - five weeks before the young fledged.

Stinson (1977) calculated the growth rate constant (K) of the twenty seven Osprey chicks studied in 1975 to be .12, and he found the time required for these chicks to grow from 10 to 90 percent of their asymptotic weight to be 36.7 days. In 1985, K and t_{10-90} were .13 and 37.2 days respectively. The small differences in these values may be explained by the fact that Stinson included measurements taken on young of four and five young broods and since there is a negative correlation in terms of brood size and the weight of the chicks at last weighing (Stinson 1977), one might expect a similar correlation between brood size and growth rates. A small sample size in 1985 prevents me from making such a correlation. Average asymptotic weight of the young was not significantly different (oneway anova, P=.727) in 1985 - 1564 grams (S.D.= 195.240, N=14) - compared with the 1975 value of 1587 grams (S.D.=149.518, N=16), using

Stinson's (1976) data on young in one, two and three young broods.

In 1985, the amount of time the male spent perched near the nest and the rate of delivery of fish to the unfledged young significantly decreased compared to ten years earlier. In 1975, the males spent 43.006 percent (S.D.=6.2675, N=69) of the day near the nest (Stinson 1976) in contrast to only 29.932 (S.D.=14.949, N=52) percent in 1985. These average inactive times are significantly different (oneway anova, P=.000). The delivery rate declined from .527 fish/hour (S.D.=0.06375, N=69) in 1975 (Stinson 1976) to .351 (S.D.=0.06375, N=52)fish/hour in 1985. These rates are significantly different (oneway anova, P=.000). It appears these decreases in both fish delivery and inactive time reflect an unavailability of food. In 1985, Chesapeake Bay Ospreys apparently hunt more and deliver less fish than they did ten years before.

Nest switching behavior has been noted previously (Fernandez and Fernandez 1977, Judge 1981) and was well documented by Poole (1982a) in his study of 19 nests in the Westport River estuary of southeastern Massachusetts. There, nests are in close proximity, and a number of nest switches were noted including one that resulted in a five-young assemblage in a formerly three-young nest. As with our observations - at least initially - all the young

were usually fed, but there is no mention of aggression similar to that which we observed in 1985. Previous studies (Judge 1981, Fernandez and Fernandez 1977) reported vagrant young being chased away by the adults of the nest. Though our observations attested to the initial tolerance of nest switching, adults and particularly the young of the nest became intolerant of intruding young and were often observed harassing them early in the post-fledging period.

As part of a study of the reproductive and feeding ecology of Ospreys nesting along the eastern shore of the Chesapeake Bay, Spitzer (1985) reported that 83 percent of the males dispersed less than 10 kilometers. Poole (1982a) has collected data to suggest a high degree of relatedness among the Westport Ospreys. Ospreys have a remarkable fidelity to the original nest site which most likely results in relatedness among birds nesting close together (Poole 1982a). Poole has postulated that kin selection explains the fact that Ospreys feed fledglings that are not their own. However, if the population is food-stressed, then one would expect the birds to be reluctant to feed altruistically. As stated previously, the birds studied in 1985 grew intolerant of intruding young approximately ten days into the post-fledging period.

Although Stinson (1977) did not observe any nest switching, sibling aggression or brood reduction in Ospreys

in 1975, other studies (Knight 1932, Poole 1979, Judge 1980, Jamieson et al. 1983) have noted the incidence of sibling aggression, and one report (Poole 1982b) has implicated food shortage as the possible cause of sibling aggression and subsequent brood reduction of nesting Ospreys. Knight (1932) noted one brief occurrence of aggression between two very young Osprey chicks. In Canada, eighteen incidents of aggression were recorded during 449 hours of observation of eight nests during the summers of 1978 and 1980 (Jamieson et al. 1983). There, aggression was noted to be more common later in the nesting period (when young were approximately four to five weeks old) and more prevalent in three-young than two-young broods. There appeared to be no fish shortage in the study area and the average rate of delivery of fish (.48 fish/ hour) is similar to that found by Stinson (1976), but is greater than the rate found in 1985. Jamieson et al. (1983) concluded that since most aggression was observed in these three-young broods, then perhaps competition for food, even if relatively abundant, results in aggression. In Florida Bay, Poole (1979) has documented the consistent aggression of one nestling against its nestmate. Measurements gathered in the days during and after witnessing the aggression revealed a significant difference in size and weight between the aggressor and the intimidated sibling - differences very similar to those I

observed in Chesapeake Bay Osprey young in 1985. Poole (1982b) noted that sibling aggression could be turned on and off with the degree of hunger of the dominant young, which argues that food availability does in fact influence this behavior. The aggressive young he studied nearly always stopped fighting after being fed - a finding identical to ours. Hatching asynchrony, as well, might have influenced the incidence of sibling aggression and the subsequent brood reduction observed in these Florida Bay Ospreys (Poole 1982b). Third chicks in food-stressed colonies grew significantly slower than their siblings (Poole 1982b). In short, Poole (1979, 1982b) offered evidence to suggest that sibling aggression is due to food scarcity and to a lesser degree, hatching asynchrony. The aggression, in turn, is important in causing brood reduction; subordinate siblings were forced out of the nest, or more commonly, denied access to food. These findings support the conclusion of Lack (1954, 1966) which predicts sibling aggression during times of food scarcity.

Some of our results based upon data collected during the summer of 1985 are easily explained, but others seem paradoxical or, at least, puzzling at first glance. Young of broods five, six and seven fledge significantly later than the other young. These later fledging times coincide with a substantial amount of sibling aggresion and/or brood

reduction observed in these nests. These results, then, suggest delayed maturation as a result of sibling aggression. Yet, at these same nests, not only were the occupants the recipients of the greatest amount of calories of fish, but their average daily energy requirements appeared to have been met. Such a result is contrary to expectation, particularly if sibling aggression and brood reduction are associated with food scarcity.

But a closer examination within broods is revealing. Though the occupants of nest five received a large amount of fish, some was left uneaten and a disproportionate share was eaten by the adult female and the dominant young. Based upon our bites data, the dominant young ate twice as much as the subordinate young (Table 7). Because the subordinate young was intimidated from eating, calls from it and subsequently from the adult female appeared to result in more fish being delivered to the nest. Also, of all adult females of the two-young broods, this female ate proportionately more than her young. It is conceivable her energetic demands were greater than others due to a host of factors including size, quality of feeding during courtship, demands of egg-laying, et cetera (Poole 1985, personal observation). Similar vocalization episodes were noted in nest six in which the adult female was the principal caller. These episodes may explain the quantity of fish delivered to

this nest. In nest seven, a three-young brood may have been the stimulus for more fish delivered. Indeed, the male of this nest was inactive the least (Table 17) and was responsible for the highest rate of delivery of fish (Table 15) than any other adult male. The young of this nest were vocal as well, and it was our impression that the subordinate young (Y2) was inordinately vocal. On a number of occasions this young was neglected during feeding either through intimidation by the ranking siblings or by lack of access to the adult female when she distributed the food. So, it appears that even though a substantial amount of calories are being delivered to these nests, in at least two cases (nests five and seven), the young are receiving disproportionate shares.

Estimation of the energy requirements of Ospreys are based upon a model developed by Wiens and Innis (1974). Though the model appears adequate, the estimate is based upon a population of Ospreys in Oregon in 1971 (Lind 1976). One might expect this estimate to be sensitive to population density and age class distribution. Also, no allowance is made for the change in energy demand with age (i.e. one average value is computed for a nestling, one for a fledgling, et cetera). In his study of Ospreys in Africa, Prevost (1982) computed the caloric demands of a two kilogram Osprey, which is about the size of an adult female,

to be as much as 570 kilocalories/day. This estimate is more than twice that of Lind's (1976). In light of Prevost's findings, then, the disparity between the kilocalories of fish required to meet the daily energy requirement and the kilocalories delivered to the nest is somewhat less.

Sex of the hatchling and hatching asynchrony appear to be important in facilitating aggression and brood reduction. I have demonstrated that in terms of asymptotic weights and growth rates there is a substantial difference between male and female young. Females grow faster and grow to be heavier than their counterparts. In brood one, even though Y1, a female, was born on the same day as Y2, a male, Y1's growth rate surpassed that of the latter in the second week of development (Figure 1). However, being hatched a day or two before a nestmate confers an advantage as well. In brood seven, the male was hatched a day before one female (Y1) and two days before the other (Y2). This male was able to maintain dominance over the females even though the females eventually grew to greater weights. The five day difference in age of the two young of nest six was probably in part responsible for the death of the one at ten days of age. These findings are consistent with Stinson's (1979) views, whereby he proposes that the reason for the predominance of cainism in raptors is the fact that raptor

chicks hatch asynchronously. This usually permits the dominance of the older chick over the younger one. Stinson (1979) explains further:

> In small brooded species with asynchronously hatching young, every nest is preadapted to 'Cain and Abel' battle (Brown 1955). In these situations, the older chick risks little by attacking its sibling and gains much insuring that it will never outcompete it for the possibly limited food supply.

However, the ultimate cause of sibling aggression and brood reduction is very probably food shortage. Although there is a positive correlation between sibling aggression and calories delivered to the nest, such a relationship may be explained by ultimate rather than proximate factors (Mock 1984). Though aggressive young are also the recipients of lots of food, the aggression may reflect an anticipated food need. Mock (1984) has commented:

> The apparent paradox of vicious sibfighting amidst a surfeit of food has led a number of workers (e.g., Wynne-Edwards, 1962; Skutch, 1967; Brown et. al., 1977; Gadgett, 1977) to the erroneous conclusion that food must be limiting. At a second glance, however, it should not be surprising for an a-chick that can reliably expect to face a time of food shortage (e.g., when the sibs collective growth requirements peak) to preempt the survivor's role as early as possible, while its size advantage is maximal (O'Conner, 1978; Stinson,

> 1979). If so, then there is no specific predicted relationship between the timing of sibling aggression and subsubsequent brood shortages, which may or may not materialize in a given season. In general, sib attacks do not seem to be restricted to moments of parental feeding (Meyburg, 1977: personal observation).

Not all of the attacks documented in this study were during feeding. In fact, a number of the posturing behaviors occurred in the absence of food. Additionally, even though broods five, six and seven received large amounts of fish, the average rate of delivery to these nests (mean=.424, S.D.=.145, N=24) is still significantly less (oneway anova, P=.000) than the rate of delivery in 1975 (mean=.540, S.D.=.0642, N=69). If we assume equal-sized fish, then the males were delivering significantly less fish in 1985 than ten years earlier. So, both proximal and ultimate food shortages appear to explain the relative predominance of sibling aggression among Chesapeake Bay Ospreys in 1985.

In 1985, the growth and behavior of young Chesapeake Bay Ospreys is markedly different from that exhibited ten years ago, and it is likely that these Ospreys are suffering from a food shortage. The intolerance of altruistic feeding, the occurrence of sibling aggression throughout the breeding season in all multi-young broods, the ability of this aggression to be turned on and off with the hunger of the dominant chick, the incidence of brood reduction in our

study nests as well as in Spitzer's (along the eastern shore of the Bay), the significant 35 percent decrease in food delivery rates and in the amount of time the male spends perched near the nest all seem to indicate that fish are not as plentiful as they once were. Apparently the Osprey population today has reached the carrying capacity of the Bay. This carrying capacity is probably substantially less than it was fifty years ago, when, it has been estimated, five times as many Ospreys hunted the Bay's waters (Stinson and Byrd 1976). Further studies of the Osprey may not only reveal more about the health of the Chesapeake Bay Osprey population but more about the overall health of the Bay.

APPENDIX A

Description of Nest Sites

All nests studied were located in Mathews and Lancaster counties, Virginia. Although I ascribed a number 1-7 to each of the nests, the number in parenthesis corresponds to nest numbers as recorded by Dr. Mitchell A. Byrd.

Nest 1 (22) (Mathews county, New Point 7.5 minute Geological Survey Quandrangle), on a former fuel tank platform 25 meters to the north of old Garrett's Wharf, fledged two young (two eggs never hatched).

Nest 2 (21) (Mathews county, New Point quandrangle), on the shore side of old Garrett's wharf building, fledged two young (one egg never hatched).

Nest 3 (21) (Mathews county, Mathews quandrangle), on red day marker number 6 at the entrance of Queens Creek, fledged two young (one egg never hatched).

Nest 4 (25) (Mathews county, Mathews quandrangle), on red navigation light number 8 at the entrance of Queens Creek, fledged two young (one egg never hatched).

Nest 5 (6) (Lancaster county, Irvington quandrangle), on red day marker number 6 at the entrance of Carter Creek, fledged two young (one chick died within the first seven days).

Nest 6 (7) (Lancaster county, Irvington quadrangle), on green navigation light number 7 at the entrance of Carter Creek, fledged one young (one chick died within the first 10 days after hatching and one egg never hatched).

Nest 7 (16) (Mathews county, New Point quadrangle), on an old anchor platform in Dyer Creek 30 meters from shore, fledged three young.

APPENDIX B

Length-weight relationships[1] of fish eaten by the Ospreys (W or Y = weight in grams, L or X = length in millimeters).

Atlantic Menhaden	Ln W = -12.075 + 3.215 Ln fork L
Atlantic Croaker	See Dexter Haven (Bibliography)
American Eel	Log W = -6.56 + 3.34 Log L
Hogchoker	Log W = -3.71095 + 2.65844 Log L
White Perch	Log W = -5.172 + 3.190 Log L
Summer Flounder	Log W = -5.8759 + 3.3238 Log L
White Catfish	Log Y = 1.9791 + .1689 Log X
Oyster Toadfish	Log W = -5.223 + 3.223 Log L
Spotted Seatrout	Log W = -4.423 + 2.861 Log L
Butterfish	Log W = -5.1852 + 3.2646 Log L

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[1]for sources, see the bibliography

APPENDIX C

Calorie and moisture content of fish included in the diet of Ospreys.

Species	cal./mg.[1]	%Moisture[2]	kcal.[3]
American Eel	9.175	67.0	303
Needlefish	7.400	78.0	163
Atlantic Menhaden	6.960	67.9	223
Atlantic Croaker	6.925	78.4	150
White Catfish	6.620	72.3	183
Spotted Seatrout	6.500	79.9	131
Hogchoker	5.967	79.5	122
Summer Flounder	5.625	78.8	119
Cutlassfish	5.133	77.0	118
White Perch	4.967	79.2	103
Oyster Toadfish	4.667	75.0[4]	117

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[1] dry weight

[2] from Virginia D. Sidwell (see Bibliography)

[3] kilocalories per 100 grams of wet weight

[4] estimated from an average value of the other fish

APPENDIX D

Age (days) and weights (grams) of the young. Weight is listed in order of Y1's, Y2's, and Y3's. Fledging (F) dates are in parentheses.

	Nest 1	Nest 2	Nest 3
Age at Initial Weighing	Y1 = 1 Y2 = 1	Y1 = 2 Y2 = 4	Y1 = 9 Y2 = 8
May 21	--'--	67, 113	315, 253
May 25	60, 55	175, 295	460, 365
May 28	95, 70	270, 405	610, 515
May 31	220, 160	420, 600	900, 778
June 4	313, 280	595, 830	1025, 945
June 7	650, 445	790, 1075	1200, 1150
June 10	640, 570	820, 1065	1250, 1215
June 13	990, 750	985, 1250	1350, 1300
June 19	1325, 1065	1215, 1500	1365, 1375
June 22	1450, 1235	1350, 1650	1390, 1350
June 24	1515, 1250	1335, 1635	1355, 1415
June 27	1640, 1380	1300, 1615	1340, 1415
July 1	1765, 1415	1330, 1590	F (6/29), F (6/29)
July 4	1660, 1445	1325, 1510	--, --
July 8	1595, 1375	F (7/8), F (7/7)	--, --
July 11	1360, 1160	--, --	--, --

July 15	F (7/13), F (7/13)	--, --	--, --

	Nest 4	Nest 5	Nest 6
Age at Initial Weighing	Y1 = 3 Y2 = 4	Y1 = 2 Y2 = 4 Y3 = 2	Y1 = 3 Y2 = 2
May 21	100, 145	--, --	60, --
May 25	320, 385	45, --, 35	160, 40
May 28	393, 500	50, 25, 25	240, 53
May 31	425, 565	70, 65[1], --	380, 75
June 4	665, 855	190, 135, --	580, -[2]
June 7	825, 1075	305, 205, --	860, --
June 10	1100, 1325	467, 300, --	945, --
June 13	1175, 1400	660, 440, --	1150, --
June 19	1375, 1585	1025, 470, --	1400, --
June 22	1350, 1675	1200, 655, --	1600, --
June 24	1375, 1700	1325, 615, --	1615, --
June 27	1400, 1725	1475, 725, --	1650, --
July 1	1290, 1690	1590, 775, --	1700, --
July 4	1345, 1635	1585, 920, --	1585, --
July 8	F (7/8), F (7/8)	1695, 1120, --	1575, --
July 11	--, --	1160, 1190, --	1525, --
July 15	--, --	1645, 1195, --	F (7/14), --
July 18	--, --	F (7/18), 1235	--, --
July 22	--, --	--, 1175, --	--, --

July 25	--, --	--, F (7/25), --	--, --

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[1]died at approximately six days of age

[2]died at approximately ten days of age

Age at Initial Weighing	Nest 7 Y1 = 6 Y2 = 5 Y3 = 7
May 21	220, 100, 270
May 25	370, 185, 443
May 28	395, 190, 520
May 31	750, 290, 755
June 4	855, 540, 1025
June 7	1175, 755, 1215
June 10	1200, 960, 1235
June 13	1390, 1175, 1290
June 19	1620, 1500, 1435
June 22	1810, 1725, 1525
June 24	1765, 1700, 1465
June 27	1765, 1815, 1440
July 1	1517, 1740, 1415
July 4	1685, 1660, 1375
July 8	F (7/8), 1660, F (7/8)
July 11	--, F (7/11), --

APPENDIX E

Our field notes on sibling aggression include:

May 29, 1985 (Nest 7): Y1 (ranking female) takes three pecks at the little (low-ranking) one (Y2). Later that day: Y3 (ranking male) takes four pecks at Y1 - pecks Y1 into submission. Later that day: Y1 takes five pecks at Y2 - primarily during feeding.

July 10, 1985 (Nest 7): Y3 challenges Y2 for fish - much flapping ensues and Y3 administers 3 severe pecks to Y2.

June 19, 1985 (Nest 5): Y2 (low-ranking male) does not eat, but appears to call for food , but then Y1 (ranking female) displays dominant posture and Y2 stops calling and assumes submissive posture.

June 22, 1985 (Nest 5): Adult female seemed to have preference to feed Y1 - Y1 gets fed first; Y2 backs off when Y1 wants to eat.

July 1, 1985 (Nest 5): Y2 tries 1 bite; Y1 delivers peck driving Y2 into submission. Later that day: Y2 eats first 14 bites, then Y1 delivers 2 pecks and Y2 quickly goes into submission (The adult female never interferes with the sibling aggression).

July 22, 1985 (Nest 3): Y1 gets second fish but is pecked a few good times in the process - Y2 pulls some feathers out of the back of Y1's head - Y1 flies to the

woods with the fish to get away.

Our field notes on behaviors exhibited by the occupants of nest five include:

May 31, 1985 (Nest 5): The female is "having a fit" - the adult female will not cease vocalizing when the male came without a fish - the male stayed only a couple of minutes.

June 10, 1985: After the first fish, the female appears to get after the male to leave.

June 19, 1985: Y2 (low-ranking male) does not eat but does appear to call for food - makes a try to eat but Y1 (ranking female) gives dominant posture. Later that day: Adult females of nest five and six do lots of calling today - appear to be calling for food.

July 8, 1985: The young's apparent cry for food is a muted one. Four minutes later, the female leaves to hunt.

July 1, 1985 (1648 hours): Y2 continues to call vigorously - female finishes with the first fish - both Y2 and the female call in unison. (1719 hours): female leaves to hunt - returns at 1736 hours with an eight-inch menhaden (1836 hours): female returns with a six to seven inch menhaden - Y1 delivers a blow to Y2 as they manuever for a position to feed. Y2 then backs off and continually calls...thirteen minutes later female leaves to hunt.

APPENDIX F

Our field notes on nest switching behavior include:

July 16, 1985 (1620 hrs.): Y2 (of nest 1) fights with unidentified intruder young for menhaden - with its beak, the intruder grabs the toes of Y2 and eventually succeeds in getting fish. (1635 hrs.): While Y2 eats croaker by self, unidentified young tries to steal and receives 5 pecks - Y2 retains fish. (1803 hrs.): Y2 fights for and succeeds in getting 3 to 4 inches of fish. Unmarked young tries to steal and Y2 delivers about 10 pecks and succeeds in keeping the fish.

July 1, 1985: Y1 of nest 3 lands on pole perch (green channel marker) beside nest 4.

July 8, 1985: Y1 of nest 3 ventures to nest 4 (25 meters away) after nest 3 adult male appears reluctant to bring food to the nest - Y1 (Nest 3) then flies to pole perch and lands on the back of the adult female of nest 4 and balances there ... a few moments later, Y1 returns to nest 4.

July 11, 1985: The adult female and Y2 of nest 4 call (seemingly one of annoyance) as Y1 of nest 3 perches beside nest 4.

July 15, 1985: Y1 of nest 3 flies to nest 4 and lands. Then, Y1 of nest 4 flies from perch tree and with

outstretched talons lands on Y1 (Nest 3) - feathers fly and Y1 (Nest 3) leaves only to make a swoop at Y1 (Nest 4) before going back to nest 3.

July 18, 1985: Y1 of nest 3 chases away Y2 of nest 4 - the young of the nests do not seem to tolerate each other anymore.

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VITA

Peter Kleppinger McLean was born August 19, 1956 in Charlottesville, Virginia and was graduated from Lane High School in 1974. He entered the University of Virginia that fall and completed his studies there the Spring of 1978 with a B.A. in environmental science and with biology and history as minor areas of study. Before entering the masters program in biology at the College of William and Mary in 1984, Peter taught biology, history and earth science at the Virginia Episcopal School of Lynchburg, Virginia, was assistant director of admissions of Randolph-Macon Woman's College, and worked as a ranger in Yellowstone National Park.